

What is claimed is:

1. An inductive ignition system for an internal combustion engine operating at a voltage V_c substantially above the standard 12 volt automotive battery with one or more ignition coils T_i and associated power switches Sw_i , where $i = 1, 2, \dots, n$, with each coil having a primary winding of 5 turns N_p and inductance L_p , and a secondary high voltage winding for producing high voltage sparks of turns N_s and inductance L_s , the primary and secondary winding defining a turns ratio N_t equal to N_s/N_p , the coils being of low inductance with one or more large air gaps within their magnetic core, with primary inductance L_p below 600 μH and producing spark of peak current I_s above 200 ma, the system further including means for providing the higher voltage V_c and 10 controlling the charging and spark discharging of the ignition coils from said voltage V_c in a controlled sequential manner, and further including connection means for connecting the coil T_i secondary high voltage end to a sparking means which substantially reduces EMI following spark breakdown, the system further including electronic control means for receiving signals to fire the sparking means in their proper order, the main improvement of the system being the use of one or 15 more biasing magnets in said one or more of air gaps in the magnetic core of said low inductance coils to reduce the magnetic core area by approximately 40% for the same coil stored energy, to produce a system that as a whole is more versatile and smaller than prior such systems for the same high coil stored energy.
2. The ignition system of claim 1 wherein a micro-controller (MCU) is used for most of the 20 electronic controls that includes generating the charge or dwell time T_{ch} and steering such charging or energizing of the ignition coils in the proper sequence, and firing the spark plugs associated with such coils.
3. The ignition system of claim 2 wherein said micro-controller identifies the cylinder to be fired during engine cranking by sensing a voltage from a few turns of each coil by having all the coils 25 fired simultaneously during cranking, and once identified, to then have the MCU shift to sequential firing with the proper firing order to run the engine.
4. The ignition system of claim 1 wherein the said coils have open-E type magnetic cores at the high voltage end wherein said one or more biasing magnets are located.
5. The ignition system of claim 4 wherein the magnetic core of said coil is laminated of non- 30 circular cross-section wherein two biasing magnet are used, one each at the core open ends.
6. The ignition system of claim 4 wherein the magnetic core of said coil is of circular cross-section and wherein one annular ring type biasing magnet is used at the core open end.
7. The ignition system of claim 4 wherein said core is contained in a housing with the center core leg in the housing and the outer legs outside of the housing.

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8. The ignition system of claim 4 wherein between the end of the high voltage winding of said coil and the high voltage connection of the sparking means is included a spiral winding of steel wire wound over a core of magnetic material which has a much higher resistance at and above 1 MHz relative to the DC resistance.
- 5 9. The ignition system of claim 1 wherein said connection means are spark plug wire with spiral winding of wire of high magnetic permeability over a core including magnetic material which exhibits high loss at 1 MHz or higher frequency relative to DC.
10. The ignition system of claim 1 wherein said sparking means are spark plugs with capacitance over 30 pF achieved by electroless chemical dip copper coating of the insulator surfaces.
- 10 11. The ignition system of claim 10 wherein said insulator is Alumina strengthened with approximately 20% or higher zirconia.
12. The ignition system of claim 10 wherein said spark plug has a halo-disc type firing end with recessed or concave high voltage insulator.
13. The ignition system of claim 13 wherein said firing end has a ground ring about the center high
15 voltage electrode wherein said ring is held by four axial supports defining four slots through which air-fuel mixture can flow.
14. The ignition system of claim 13 wherein said axial supports define a cone with included angle θ between 30 and 90 degrees.
15. The ignition system of claim 10 wherein said spark plug has recessed firing end insulator with
20 large diameter center conductor of diameter approximately 0.15" along the threaded spark plug shell section to provide higher capacitance than normal along this section.
16. The ignition system of claim 15 wherein said center conductor is high thermal conductivity material from the collection of copper, brass, and other high conductivity materials.
17. The ignition system of claim 1 wherein said switches Swi are IGBTs and wherein their gates
25 are turned on slowly by including high value resistance in series with the gate to substantially reduce the output voltage overshoot upon switch Swi turn-on.
18. The ignition system of claim 1 including boost converter for raising said battery voltage Vb to a higher voltage Vc.
19. The ignition system of claim 1 wherein said boost converter is bi-directional and includes two
30 inductor windings with biasing magnet for the magnetic core.

20. An ignition system for an internal combustion engine with more than one ignition coil T_i and associated power switches Sw_i , where $i = 1, 2, \dots, n$, with control means for charging and spark discharging of the ignition coils through sparking means in a controlled sequential manner, the system further including micro-controller (MCU) electronic means for receiving signals to fire the
5 sparking means by having at least one pin P_i associated with each coil T_i , said MCU including A/D converter capability, the MCU means overall being designed to identify the cylinder that is under compression and is to be fired during that ignition firing, called the reference signal, the reference signal being found during the initial engine start up and engine cranking by simultaneously sensing a voltage from a few secondary winding turns of at least one coil associated
10 with each engine cylinder, wherein at least one coil per cylinder are simultaneously fired during engine cranking, providing a sense signal to its associated MCU control P_{in} , which the MCU compares among all the other cylinder pins P_i and finds the maximum or minimum which it identifies that as the reference firing cylinder, from which reference it can then perform proper sequential ignition firing to allow the engine to run properly, without having been provided with
15 a cam or phase signal.